Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Apr 2020

Project Reference Number

NIA_NGTO053

Project Registration

Project Title

Evaluation of Travelling Wave based Transmission Line Protection for Low-Fault Level Networks

Project Reference Number

NIA_NGTO053

Project Licensee(s)

National Grid Electricity Transmission

Project Start

July 2020

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Linwei Chen

Project Budget

£236,270.00

Summary

The nature of power system faults is changing with the growing integration of renewable generation through power electronic converters. The fault level of transmission systems may decrease due to the replacement of conventional synchronous generators with converter fed renewable generation which delivers significantly less fault current. This project will assess the viability of applying travelling wave based protection to transmission lines operating under low-fault level conditions. The impact of communication delay/asymmetry and bandwidth limitation on protection performance will be analysed to inform utilities with best practices of using Travelling Wave protection.

Nominated Contact Email Address(es)

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Problem Being Solved

Transmission networks were traditionally connected with synchronous generators, which have a large amount of energy stored in rotating masses to provide high short-circuit currents during power system faults. The growing deployment of power electronics based renewables, such as wind turbines and solar panels, to displace synchronous generation is reducing system fault levels. There is an increasing possibility of new scenarios where the existing protection methods may not be sufficiently fast/reliable to detect and clear low fault currents, thus increasing the likelihood of wide network stability issues. The industry has recognised an increasing need to establish effective protection methods and strategies for the future electricity system with more renewable generation connections.

Method(s)

Travelling Wave (TW) based protection has been identified as a promising alternative to conventional solutions (e.g. distance and overcurrent) in the literature as TW can offer significantly higher sensitivity and a faster operating response to power system faults.

When a short-circuit fault occurs on a transmission line, the instantaneous voltage at the fault location suddenly collapses to a low value

and travelling waves propagate in both directions away from the fault and along the line. The waves travel at almost constant velocity (v = 290m/μs), slightly less than the speed of light, and they arrive at the line ends at a time that depends on the fault location and the line length. TW relays use this principle to implement differential, distance and directional comparison protection schemes and provide an extremely accurate fault location decision.

To support discrimination of travelling waves caused by switching transients or system faults, two TW devices usually would be installed for a circuit, one at each end, and communicate with TW samples. Due to a high sampling rate (over 1MHz) requirement, a direct fibre link or high-bandwidth network (e.g. Wavelength Division Multiplexing – WDM) is normally required to transfer sampling data between two ends. However, the Operational Telecommunication (Optel) network within NGET is currently based on Synchronous Digital Hierarchy (SDH) at low bandwidth, which could bring challenges to the TW application. This project will carry out Hardware-in-the-Loop testing to evaluate the feasibility of adopting TW protection with the existing Optel network and propose best practices for TW based protection deployment.

Scope

The scope of this project can be divided into the following parts.

1. Review of existing available solutions based on TW protection and practical experience in the world,
2. Review of lab testing methodologies for TW protection,
3. Transmission network study to identify scenarios that can cause reduced short-circuit levels,
4. Hardware-in-the-Loop testing with commercial TW protection products under the developed low short-circuit level scenarios,
5. Assessment of communication impacts on the protection performance and recommendations for future deployments.

Objective(s)

The project aims to evaluate the effectiveness of TW protection applied to transmission lines on low-fault level systems and understand the impacts of communication delay/asymmetry and bandwidth limitations on the operating performance, as expressed in terms of dependability, stability and speed.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

If successful, this project will deliver the following key outcomes:

- Evaluation of the suitability of applying TW protection to transmission lines on low-fault level systems,
- Assessment of protection performance under different communication network conditions,
- Guidance on Factory Acceptance Testing (FAT) for TW protection solutions and future deployment considering communication limitations.

Project Partners and External Funding

None

Potential for New Learning

The project will generate new learning for utilities on the viability of using TW protection to mitigate low-fault level issues and provide understanding of how to reliably deploy the solutions considering existing communication network limitations.

Scale of Project

The project will study the South East region within the NGET network, where DC interties and renewable generation is connected to the grid. A critical part of the project is understanding the scenarios that result in low short-circuit currents, which previous work has indicated is detrimental to the operating performance of conventional distance and overcurrent protection. TW protection relays are expected to be less susceptible to the impact of fault current reduction, but what is an acceptable level of reduction needs to be determined. A laboratory based test platform will be established and used to investigate the performance of a TW protection scheme for the studied scenarios.

Technology Readiness at Start

TRL2 Invention and Research

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

The work will require desktop simulation studies and laboratory based testing of commercial hardware.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£236,270

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

The work aims to evaluate the effectiveness of using TW protection solutions to mitigate protection risks associated with low-fault levels. Financial benefits would be primarily derived from the reduction of loss of supply costs associated with system stability issues due to protection mal-operations. The savings will be estimated based on the specific outcomes generated from the project.

Please provide a calculation of the expected benefits the Solution

Not applicable – this is primarily a research project.

Please provide an estimate of how replicable the Method is across GB

The learning from this project will provide Network Licensees across GB with a more informed understanding of using TW protection under different communication network conditions and how to validate performance. The knowledge gained will support key strategic and investment decisions with respect to mitigating or resolving protection risks due to low-fault levels.

Please provide an outline of the costs of rolling out the Method across GB.

Roll out with new projects – no retrofit envisaged at this stage.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☑ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☐ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

The outcomes from the project will be available to the general public via the ENA portal and conference or journal publications.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

This project fits within the Managing Assets value area of the Electricity Innovation Strategy.

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

To the best of our knowledge, this work has not been conducted before. This review has included the ENA smart portal, and supply base (including Universities and EPRI). There are a number of similar-sounding projects, however, they are examining and assessing problems or risks, e.g. low fault level / inertia issues and the associated impacts on fault clearance time. This project will investigate a corresponding solution using new technologies, i.e. travelling wave.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

The project will evaluate the effectiveness of TW protection for future cleaner energy systems at low-fault levels. TW protection has not been trialled in the UK due to high requirements on communication networks. The study is therefore aimed to develop a guideline for utilities to deploy TW protection solutions considering Optel network existing limitations and future reinforcement if necessary.

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

The nature of a research programme means it inherently carries a risk that the research may be unsuccessful or identify unforeseen challenges/costs to implementation. The NIA funding offers the most appropriate route for the National Grid Electricity Transmission (NGET) to assess the viability of using TW protection for low-fault level systems and the learning can be applied to all Network Licensees.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

The inherent risk of the project is detailed above and the learning from the project will be directly relevant to all Network Licensees. For this reason, NGET believes this project is appropriately funded through NIA, and material from the project will be available to the general public via the ENA portal.

This project has been approved by a senior member of staff

☑ Yes